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Aerosol properties:

Chemical Process:

Gravity-wave drag:

Convective Process:

Radiative Process:

Horizontal resolution:

The e–folding time of conversion in the model is estimated to be about 45 days, which is about 10 days longer than that observed.

Figure 1 shows the zonal mean column integrated optical thickness for sulfate aerosols. There can be seen an enhancement of the vertical current for about one year after the eruption. The maximum value of enhancement is about 0.01–0.03 mm/s, corresponding with the temperature increase of 2 K.

5.2. Chemical effect of aerosols.

Volcanic aerosols can change the quantity of chemical species, such as HOx, ClOx, and NOy by heterogeneous reactions on the surface of aerosols. It causes global ozone depletion (Figure 2). Ozone depletion also changes heating rate in the lower stratosphere (Figure 3).

5.3. Temperature anomalies

The change of heating rate caused by aerosols and ozone depletion (c.f. Figure 3) leads to temperature change in the lower stratosphere (Figure 4). For about a half year after the eruption, there is no evident discrepancy by the consideration of the heterogeneous reactions on volcanic aerosols. The temperature increases in the midlatitudes and tropics with the maximum value of 1–2K. After January 1992, the warming continues until October 1993 in EXP3. In contrast, the warming rapidly disappears in EXP2. The temperature anomaly of sulfate aerosol has the maximum value of about 1.5K on SON in October 1991. By considering the heterogeneous reaction on the volcanic aerosol, overestimation of the warming disappears. Figure 5 shows the residual mean vertical velocities for EXP1, EXP2, and EXP3. There can be seen an enhancement of the vertical current for about one year after the eruption. The maximum value of enhancement is about 0.01–0.03 mm/s, corresponding with the temperature increase of 2 K.

5.4. Model scenarios

We conducted three series of numerical experiments with climatological SST. EXP1 was for the background case, and only background aerosols were considered. EXP2 and EXP3 were prepared for the simulation of the 1991 Pinatubo eruption. The difference of EXP2 and EXP3 was the treatment of heterogeneous reactions on the surface of sulfate aerosols. The radiative effect of aerosols on longwave/shortwave was taken into account in all scenarios. In each series, we conducted four members of ensemble experiments.

3. Characteristics of the model

Horizontal resolution: T21 (about 5.6 degree)

Vertical resolution: 32 levels (about 2km interval, up to 80km)

Radiative Process: Domain–1 k–distribution, with using 3-D profile of 20 chemical species (e.g. ozone) and aerosols predicted in the chemical scheme (On-Land).

Convective Process: Simplified Arakawa-Schubert (considering tracer updraft/downdraft).

Gravity-wave drag: Based on Takigawa et al. (1999), and modified to treat OClO and OClO2.

Chemical species: 36

Gas reactions: 85

Heterogeneous reactions: 4

Photolytic reactions: 26

Aerosol properties:

Simplified bimodal lognormal distribution based on balloon-borne observations

Composition: 75%+ sulfate acid droplet

5.1. Radiative effect of aerosols.

Volcanic SO2 is rapidly converted into sulfate aerosols. The e–folding time of conversion is estimated to be about 45 days, which is about 10 days longer than that observed. The simulated dynamic feedback is qualitatively similar to that observed. The weanery phase of the QBO is prolonged about 30 days by the 1991 Pinatubo eruption, and corresponding change can be seen in the QBO phase of temperature and ozone. The probably reason for the delay of the QBO phase is the enhanced upward current caused by the aerosol heating in the equatorial lower stratosphere.

The lower propagation of the easterly phase of the QBO was prevented over 8 months in 1991 in the observations. In contrast, it is prolonged about 30 days by the 1991 Pinatubo eruption. Our results show that the QBO phase of temperature and ozone is prolonged about 30 days by the 1991 Pinatubo eruption.